REMARKS

Favorable reconsideration is requested in view of the foregoing amendments and the following remarks.

I. Claim Status and Amendments

Claims 1-20 were pending in this application when last examined and stand rejected.

New claims 21-24 have been added. Support can be found throughout the general disclosure, for instance, at pages 2-8, ad and in original claim 1. New independent claim 21 corresponds to and replaces original claim 1 (now cancelled). Further support for the new claims, including apparatus claim 24, can be found in the disclosure, for example, at page 8-9 and Figure 1.

Claims 2, 3, 4, 6, 7, 8, and 9 are amended to change their dependency to new independent claim 21. Other minor editorial revisions have been made to claims 2-20 to better conform to U.S. claim form and practice. Such revisions are non-substantive and not intended to narrow the scope of protection. They include revising the claim language to provide proper antecedent basis for the recited terminology.

Claim 1 has been cancelled without prejudice or disclaimer thereto. Applicants reserve the right to file a continuation or divisional application on any cancelled subject matter.

No new matter has been added.

Claims 2-24 are pending upon entry of this amendment.

II. Foreign Priority

In item 1 on page 2, the Official Action acknowledges the claim for foreign priority claim under 35 U.S.C. § 119(a)-(d) or (f), but indicates that a certified copy of the foreign priority document has not been received at the USPTO.

It is believed that that a certified copy of the foreign priority document should have been submitted by the International Bureau to the USPTO. Thus, please check again the USPTO files for the certified copy and acknowledge receipt of such. Applicants will consider submitting a certified copy, if such can be found at the USPTO.

III. Prior Art Rejections

Claims 1, 2, 7-11, 16, and 20 were rejected under 35 U.S.C. § 103(a) as obvious over YAMAZAKI (US 4,588,610) in view of INAYOSHI (JP 02-182883) for the reasons in item 2 on pages 2-3 of the Official Action.

Claims 3, 12, and 17 were rejected under 35 U.S.C. § 103(a) as obvious over YAMAZAKI in view of INAYOSHI and RAY (Jpn. J. Appl. Phys., vol. 32, pp. L1559-L15611, 1993) for the reasons in item 3 on pages 3-4.

Claims 4, 5, 13, 14, 18, and 19 were rejected under 35 U.S.C. § 103(a) as obvious over YAMAZAKI in view of INAYOSHI and HORIOKA (US 4,595,601) for the reasons in item 4 on pages 4-5.

Claims 6 and 15 were rejected under 35 U.S.C. § 103(a) as obvious over YAMAZAKI in view of INAYOSHI and AOYAMA (JP 04-146620) for the reasons in item 5 on pages 5-6.

These rejections are respectfully traversed and will be discussed together below. It is noted that YAMAZAKI and INAYOSHI are used throughout as the first reference and second reference, respectively, in each rejection. Accordingly, it is the patents to YAMAZAKI and INAYOSHI on which the rejection falls, for the reasons noted below.

The Official Action relied on YAMAZAKI and INAYOSHI to reject claim 1 on the basis that they disclose technical matter partially identical to that of the claims but basically different in principle of operation of substrate-surface treatment from the claimed invention as amended.

It is believed that the present amendment overcomes the rejections, because the cited references fail to disclose or suggest each and every element of new independent claim 21, as will become evident from the discussion below, which makes reference to the attached Reference figures 1 and 2.

1. Difference between YAMAZAKI and the claimed invention

YAMAZAKI discloses a method for forming a silicon nitride film by means of a photo-assisted CVD apparatus. The following is described as technical matter equivalent to that of the present invention. Namely, a pressure of 0.1 - 10 torr (0.00013 - 0.013 atmospheric pressure) is disclosed, which pressure range partly overlaps with the range of 0.001 - 1 atmospheric pressure in new independent claim 21. The use of a low-pressure mercury lamp as an ultraviolet light source is also disclosed.

However, YAMAZAKI fails to disclose or suggest the other features of new independent of claim 21. For instance, YAMAZAKI does not disclose "applying a negative bias voltage to the substrate and accelerating the emitted electrons" of claim 21, as will be discussed in more detail below. Thus, it is believed that the method in YAMAZAKI is basically different from the claimed method with respect to principle of operation for the substrate-surface treatment.

2. Difference between INAYOSHI and the claimed invention

INAYOSHI discloses an ultraviolet-excited chemical vapor deposition apparatus for forming an SiN film under excitation with an ultraviolet ray (185 nm) by use of a low-pressure mercury lamp. INAYOSHI also discloses the application of a bias voltage.

However, INAYOSHI does not disclose the remaining several feature of new claim 21, as will be discussed in more detail below.

The Official Action states that INAYOSHI discloses the application of a negative bias to the substrate at page 3, lines 6-7 of the Action. However, in INAYOSHI, it is the mesh electrode 10, instead of the base plate 4 that applies a negative bias.

Moreover, in INAYOSHI, a positive bias is applied to the substrate without applying a negative bias to the substrate, which stands in contrast to the method of claim 21. This means to apply a positive bias to the substrate in order to attract negative ions (NH_2^-, NH^-, etc.) toward the substrate, as apparent from the last passage in embodiment 1 in Cited Reference 1, i.e. "in a reaction chamber 22, an electric field is established by a mesh electrode 10 negatively biased by the electrode 11 and a susceptor electrode 5a positively biased so that ions such as NH_2^- and NH^- are attracted toward the wafer under the electric field and reacted with SiH_4 to thereby grow an SiN film on the wafer 4". This stands in contrast to the method of claim 21.

Again, new independent claim 21 calls for "applying a negative bias voltage to the substrate with respect to an electrode, the electrode having a plurality of openings through which an ultraviolet ray is allowed to pass and arranged between the light source and the substrate in a manner facing the substrate; whereby a dense plasma is produced in a region close

to the surface of the substrate and between the substrate and the electrode under a pressure within the treating container; and treating the surface of the substrate with the plasma.” INAYOSHI fails to disclose or suggest these features of claim 21.

For this reason, it is believed that INAYOSHI and the method of claim 21 are basically different from each other with respect to principle of operation for the substrate-surface treatment.

<u>3. Reasons why the method of claim 21 is not obvious over the combination of YAMAZAKI and INAYOSHI</u>

If taking account of the fact that the side to which a negative bias is applied is opposite between INAYOSHI and the present invention, it would not be easy nor obvious to modify/alter the teachings of YAMAZAKI and INAYOSHI to reach the method of claim 21. Indeed, even if YAMAZAKI and INAYOSHI were combined, they would not arrive at the claimed invention. In this regard, the "principle of substrate surface treatment" assumable by the combination of YAMAZAKI and INAYOSHI is different from that of the claimed method and apparatus. The "principle of substrate surface treatment" assumable by the combination of YAMAZAKI and INAYOSHI is considered, at most, like the upper one shown in the attached reference figure 2.

The apparatus resulting from the combination of YAMAZAKI and INAYOSHI (hereinafter, referred to as an assumed

apparatus) is considered to be composed of an ultraviolet lamp, an optical window, a mesh electrode, a power source for applying a positive bias to a substrate and so on as shown in the upper one of reference figure 2, and is similar to the apparatus of the present invention. However, the apparatus in the present invention of claim 24 (apparatus shown in the lower one of reference figure 2) and the assumed apparatus are considered basically different in principle of operation due to a greatly different "operating pressure range" for treating a substrate. This is evident from the following discussion.

The pressure range in the present invention is 0.001 - 1 atmospheric pressure, whereas YAMAZAKI describes 0.1 - 10 torr (0.00013 - 0.013 atmospheric pressure). However, the principle of operation is considered basically different between both. This is made clear from referring to the attached reference figure 1 (figure showing a relationship between a mean free path of molecules and electrons or a process efficiency and a gas pressure) and the attached reference figure 2 (comparison explanatory figure concerning the decomposition principle of a material gas between the assumed apparatus and the present invention).

The principle of operation of the assumed apparatus lies in "photo-decomposition of a material". In contrast, the operation principle of the present invention lies in "electron impact dissociation of a material through use of the electrons

emitted from a substrate surface due to ultraviolet irradiation" (see paragraph [0010] of the publication of the instant application).

In the both operations, ions or radicals are produced to enhance the reaction efficiency in a process, such as, deposition because they are chemically active. However, ions or radicals in a gas phase lose chemical activeness due to collisions with material gas molecules and return to a state before photo-decomposition or electron impact dissociation. Here, the travel distance of the gas molecule from a collision up to the next collision is called a "mean free path". The mean free path decreases in inverse proportion to the gas pressure and gas molecule size. The mean free paths of hydrogen (H_2) and methane (CH_4) at room temperature on pressure are shown in the upper one of reference figure 1.

The hydrogen molecule has a mean free path of approximately 0.0001 mm at 1 atmospheric pressure and approximately 10 mm at 1×10^{-5} atmospheric pressure. From the definition of mean free path, when 100 hydrogen atoms move a distance of 0.0001 mm, about 63 atoms experience collisions. In any case, the mean free path is considerably as short as approximately 0.0001 mm at 1 atmospheric pressure, which increases by 5 digits up to 10 mm by reducing the pressure by 5 digits down to 1×10^{-5} atmospheric pressure. As for ions and radicals, the mean free path is nearly equal to that of a gas

molecule. Meanwhile, concerning the mean free paths of electrons and gas molecules, the electron has a mean free path that is $4\sqrt{2}$ times longer than that between gas molecules because smaller in size, as shown in the upper one of reference figure 1.

The collision probability of an electron or ultraviolet light with a gas molecule increases with increasing gas pressure. Although this means a production of ions and radicals with high density, the density of ions and radicals drastically decreases along the traveling direction of electrons or ultraviolet light as shown in the upper one of the reference figure 2 due to conspicuous absorption of electrons or ultraviolet light. As a consequence, the density of ions and radicals is maximal in the vicinity of the optical window and minimal at the substrate surface under the operation principle of cited reference. The ions and radicals, caused by photo-decomposition, are to reach a distance of nearly the mean free path and hence, it is not practical because 0.0001 mm at 1 atmospheric pressure. Since it is approximately 10 mm even at 1×10^{-5} atmospheric pressure, a process using photo-decomposition is available in a several-cm reactor.

Meanwhile, the principle of operation of the assumed apparatus lies in accelerating the reaction efficiency due to collection of ions (negative ions in the case of Cited Reference B)(positive ions if conceded a little) of those produced by "photo-decomposition of a material". For radicals produced

approximately 100 - 1000 times the number of positive ions, this operation principle cannot serve. The greater part of them reacts with the optical window and gives rise to damage by etching or light transmittance reduction due to deposition. Furthermore, in order to efficiently collect ions, it is effective to increase the spacing between the substrate and the mesh electrode to a possible greater extent. For this reason, the mesh electrode is necessarily set up close to the light transmission window. From the above, concerning the dependence of reaction efficiency on gas pressure under the operation principle of the assumed apparatus, the density of produced ions is increased by increasing the gas pressure. However, due to the fact that the high ion-density region is distant from the substrate surface and that the means free path of ions is shorter, net reaction efficiency conspicuously decreases with increasing gas pressure (see the lower one of reference figure 1).

In contrast, the principle of operation of the present invention does not aim at photo-decomposing gas molecules at all. Conversely, ultraviolet light absorption by gas molecules weakens the effect of the present operation principle. Since no or less absorption of ultraviolet light by the material gas, ultraviolet irradiation can be efficiently applied to the substrate surface. See step 3 of new claim 21, which recites "irradiating an ultraviolet ray having a photon energy of 3 to 10 eV to a surface

of the substrate from a light source housed in the treating container having a light output window so as to emit electrons from the surface of the substrate." New claims 22-24 contain similar language. As a consequence, electrons are emitted based on "photoelectric effects" from the substrate surface. Due to small kinetic energy of the emitted electrons, the electrons are accelerated by applying a negative bias voltage to the substrate (step 4 of claim 21), which makes it possible to effectively perform electron impact dissociation of the material gas. Similar to photo-decomposition, in electron impact dissociation, ions and radicals are produced with high density in the vicinity of an electron source, i.e., in the vicinity of the substrate surface, as the pressure of the material gas is increased, as shown in the lower one of reference figure 2.

Even if the gas pressure increases and the mean free path of radicals shortens, the produced radicals are fully allowed to reach the substrate surface without collisions by nearing of the high-density radical regions to the same. However, if the pressure is increased excessively, the electrons newly produced by electron impact dissociation have a reduced mean free path in addition to shortening of the mean free path of the electrons emitted from the substrate surface, so that those are not sufficiently accelerated under the electric field and the occurrence efficiency of subsequent electron impact dissociations lowers. On the other hand, if the gas pressure is decreased, the

high-density region moves away from the vicinity of the substrate surface in addition to the lowering of the density of radicals due to electron impact dissociation. Since the mean free path of the electrons is approximately 5.7 times longer than the mean free path of the radicals or ions as shown in the upper one of reference figure 1, the spatial spread of the radical production region by the reduction of gas pressure surpasses the increase of the mean free path of radicals with a result that the concentration of radicals capable of reaching the substrate surface conspicuously decreases.

As a consequence, the efficiency of reaction reduces on the both sides of approximately 0.1 atmospheric pressure, as shown in the lower one of reference figure 1. Namely, as set forth in the current claims 16 - 20 of the present application, the most suitable range is from 0.01 - 0.5 atmospheric pressure. Meanwhile, the efficiency of reaction greatly reduces at 0.1 - 10 torr (0.00013 - 0.013 atmospheric pressure) in YAMAZAKI, i.e. approximately 0.01 atmospheric pressure or lower.

Based on the above, it is respectfully submitted that combining the teachings of YAMAZAKI and INAYOSHI would not yield predictable results, let alone arrive at the method and apparatus of claims 21-24. For this reason, the combination of YAMAZAKI and INAYOSHI do not render obvious claims 21-24.

In light of the arguments put forward above, Applicants respectfully submit that neither YAMAZAKI, nor INAYOSHI, taken

alone or in combination, teaches, suggests or makes obvious each and every element of new independent claims 21-24. For this reason, independent claims 21-24, and all claims dependent thereon, are believed to be novel and non-obvious over the cited prior art references, either alone or when combined.

Again, it is the patents to YAMAZAKI and INAYOSHI on which the rejection falls. The remaining secondary references of RAY, HORIOKA, and AOYAMA do not remedy the above-noted deficiencies of YAMAZAKI and INAYOSHI.

Therefore, Applicants respectfully submit that the above-noted 103(a) obviousness rejections are untenable and should be withdrawn.

VI. Conclusion

Having addressed all the outstanding issues, the amendment is believed to be fully responsive. It is respectfully submitted that the application is in condition for allowance and notice to that effect is hereby requested. If the Examiner has any comments or proposals for expediting prosecution, please contact the undersigned at the telephone number below.

The Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 25-0120 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17.

Respectfully submitted,

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APPENDIX:

The Appendix includes the following item(s):

- Reference figures 1 and 2 discussed in the above traversal to the prior art rejections. Reference figures 1 and 2 are not replacement drawing figures for the current application.